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THE IONS OF THE ATMOSPHERE[1]

As one of the results of the recent development of electrical science it is considered that throughout the air in its normal state, and in other gases in a similar condition, there exists a small number of molecules, or groups of molecules, which are distinguished from the vast host of their fellows in being electrified. Each of these electrified entities, whatever its structure, is called an ion, and of ions there are two main classes, the one containing those which are positively, the other those which are negatively, electrified. The notion of the ion, in this connection, arises from attempts to reach a simple description of the facts associated with the conduction of electricity through gases, and the hypothesis admirably fulfils its purpose.

The number of ions in the air can be greatly increased by exposing it to the influence of Röntgen rays, or to the radiations from radium or other radio-active bodies, and it is from investigations connected with this artificially produced ionization that most of our present knowledge of ions is derived. For the most interesting account of these researches I refer you to the address delivered before this section at Dunedin in 1904 by the present distinguished president of the association. For my immediate purpose I have to remind you of one result: in an electric field, in addition to the motion of molecular agitation shared by all the constituents of a gas, the ions, in virtue of their charge, acquire a velocity whose average value depends on the electric intensity

[1] Presidential address before Section A of the Australasian Association for the Advancement of Science.

and on the resistance which is offered to the movement; under the influence of the electrical forces the ions drift, as it were, in a definite direction, the positives traveling to the negative electrode, and *vice versa*, a motion in which the uncharged molecules have no part. Other things being equal, it is assumed that this drift velocity of the ions is directly proportional to the electric intensity and following the suggestion of M. Langevin, the term "mobility" has been adopted for the average velocity acquired by an ion under the influence of unit electric force. At the present time the mobility of a class of ions is its most readily determined property, and it is principally to observations of the mobility of the ions in different gases and under various conditions that we must look for a clue to the nature of the ionic structure. In all cases I shall state the value of the mobility as that of the velocity, in centimeters per second, due to an electric force represented by a potential gradient of one volt per centimeter, that is, in practical units.

Two types of ion are recognized as existing naturally in the air, the small ion, with a mobility of about one and one half under normal conditions, and another, discovered by M. Langevin,[2] and called by him the large ion, which is characterized by the very small mobility of only $\frac{1}{3000}$. To these I now add a third, which has a mobility of about $\frac{1}{100}$ under normal circumstances. It may be called, for the present at least, the ion of intermediate mobility, or the intermediate ion.

M. Bloch[3] finds in air bubbled through water ions of mobility of the order of one or two tenths; these seem to form a fourth class of ions and it would be interesting to know if they exist in air not specially treated.

[2] Langevin, *C. R.*, t. 140, p. 232, 1905.

[3] Bloch, *C. R.*, t. 145, p. 54, 1907.

The small atmosphere ions are identical with those artificially produced in air by ionizing agents which have been made the subject of such numerous researches as described by Professor Bragg in his address. There is now considerable knowledge, resumed in the beautiful kinetic theory of gases, of molecular movements and dimensions, and when it is thought that an ion moves more slowly in an electric field than would a single molecule if charged, as the ion must be made of the stuff of the gas in which it is formed, what more natural than to consider it a cluster of a few molecules? This idea has been generally adopted. The small ions are thus assumed to be of somewhat greater size than their fellow molecules, but as the mobility notably increases with decrease of pressure, and with rise of temperature, their diameter is apparently not a constant quantity.

The direct argument, which is used to support this view, considers that in the numerous collisions which occur between the charged and uncharged molecules, in many cases the kinetic energy of the latter will not be great enough to carry them away, after impact, from the attraction of the charge. The charged molecule will thus collect other molecules around it, but as the effect of the charge on the outer members of the cluster diminishes as the collection of molecules increases, the growth will cease when the size is such that the attraction of the charge at the surface of the cluster, in grazing impact of ion and molecule, is just insufficient to hold the latter as a permanent member of the ionic system. The principle involved, in calculating the value of the limiting radius, is similar to that which determines whether a comet, in its close approach to the sun, shall become a permanent member of the solar system or wander into the space from which it came. The calcula-

tion of the ionic size which has been made on these lines assumes the ions as charged, the molecules as uncharged conducting spheres, and, taking the radius of the molecules as 10^{-8} centimeters, reaches the conclusion that the radius of the ion can not exceed three times this value.

To account for the change of mobility associated with alteration of the pressure or temperature conditions, it is supposed that the clusters of molecules forming the ions consist of fewer members at low pressures and at high temperatures than under ordinary circumstances. As the temperature rises, for instance, the ion may be imagined as shedding one by one its component molecules. The mobility, however, varies continuously and not by jumps; it may, therefore, be considered, in addition, that a cluster at any temperature does not always consist of the same number of molecules. In the numerous collisions, to which an ion as a constituent of a gas is subjected, a molecule of the cluster may be lost at one, to be gained at another impact, the cluster acting on the whole as if it contained the average number of members; it is this average number which, from this point of view, must be taken as decreasing continuously with rise of temperature.

From a consideration of the slow movement of the ions in an electric field compared with that which it is assumed a single charged molecule would have in the same circumstances, it is possible, with the aid of the principles of the kinetic theory, to make an estimate of the number of molecules which go to make an ion. The argument is given in Mr. Phillips's paper on "Ionic Velocities in Air at Different Temperatures,"[4] and he calculates from his results that the positive ion at $-179°$ C. consists, on the average, of about four and a half molecules (4.63), while at $+138°$ C. the average number is only about one and a half (1.52). For the negative ion slightly smaller figures are obtained.

Such an idea of the small ion, based, either on the direct argument in its restricted form already noted, or on the calculation just mentioned, can not be considered satisfactory, and it is now shown to be unnecessary by two workers at opposite sides of the world, Mr. Wellisch at Cambridge and Mr. William Sutherland at Melbourne.

In this connection it is interesting to recall another physical problem which apparently also required for its explanation a shrinkage of the molecules with rise of temperature, that of the relation between the temperature and the viscosity of a gas. The solution of the problem was finally reached in 1893 by Mr. Sutherland, from a consideration of the influence of molecular force in bringing about collisions which would otherwise not occur, the investigation being published in his paper on "The Viscosity of Gases and Molecular Force."[5] The result of mutual attraction, only sensible at small distances, is to make the molecules, considered forceless, behave as if they had a diameter greater than the true value. As the molecular force is less effective in causing collisions the greater the velocity with which two molecules approach each other, the apparent diameter to which it gives rise is less the higher the temperature. It is now shown by the writers I have mentioned that there is a similar effect due to the ionic charge. Owing to the influence of the electrical attraction, collisions between ions and molecules take place which would otherwise be avoided, and consequently the ions act as molecules of greater than the normal size, the apparent diameter decreasing as the temperature rises.

For the movement of an ion through

[4] Phillips, *Proc. R. S.*, A, 78, p. 167, 1906.

[5] Sutherland, *Phil. Mag.*, 36, p. 507, 1893.

a gas, M. Langevin[6] has given for the mobility, k, and the coefficient of diffusion, D, the equations,

$$k=\frac{eL}{MV};\quad D=\frac{LV}{3},$$

where e denotes the ionic charge, L the mean free path of the ion, M its mass and V its mean velocity of thermal agitation. Mr. Wellisch in his investigation calculates the mean free path of the ion, taking into account the effect of the ionic charge in increasing the collision frequency, and, substituting in the above equations, reaches general expressions for the two quantities under consideration. If the mass and dimensions of the ion are taken as the same as those of the molecule the expression for the mobility becomes at 0° C.

$$k=\frac{A\eta}{\rho_1 p}\left\{1+\frac{(K_1-1)\pi A^2\eta^2}{2\rho_1 p_1^2}\right\}^{-1}$$

and that for the coefficient of diffusion at the same temperature

$$D=\frac{\eta}{\rho}\left\{1+\frac{(K_1-1)\pi A^2\eta^2}{2\rho_1 p_1^2}\right\}^{-1}$$

where A ($=1.30\times 10^{10}$ electrostatic units) is the product of the number of molecules per cubic centimeter and the ionic charge, η the coefficient of viscosity of the gas, K its specific inductive capacity, ρ the density and p the pressure in dynes per cm.^{2}, the symbols with subscripts referring to values under the standard conditions as to temperature and pressure.

To test the theory Mr. Wellisch gives the following table of comparison between the observed and the calculated values, the observed mobilities, except in the case of air, hydrogen, nitrogen and oxygen, being the results of a series of determinations recently made by him.

Gas or Vapor	Formula	Molecular Mass	$\rho_1\times 10^5$	$\eta\times 10^6$	$(K_1-1)\times 10^5$	k_{760} Calculated	k_{760} Observed +	k_{760} Observed −
Air			129	177	59	1.25	1.36	1.87
Hydrogen	H_2	2	9	85	26	6.32	6.70	7.95
Carbon monoxide	CO	28	125	163	69	1.16	1.05	1.10
Nitrogen	N_2	28	125	163	59	1.31	1 6	mean
Oxygen	O_2	32	143	191	54	1.25	1.36	1.80
Carbon dioxide	CO_2	44	196	141	96	.87	.77	.81
Nitrous oxide	N_2O	44	196	141	107	.81	.79	.86
Ammonia	NH_3	17	76	96	770	.21	.70	.76
Ethyl alcohol	C_2H_6O	46	205	83	940	.19	.32	.26
Sulphur dioxide	SO_2	64	286	122	993	.13	.42	.39
Ethyl chloride	C_2H_5Cl	64.5	288	93	1,554	.11	.32	.30
Ethyl ether	$C_4H_{10}O$	74	330	69	742	.24	.28	.30
Carbon tetrachloride	CCl_4	153.8	686	153	426	.20	.29	.30

Mr. Wellisch further shows that if d denote the coefficient of interdiffusion of a molecule through the gas,

$$\frac{D}{d}=\left\{1+\frac{(K_1-1)\pi A^2\eta^2}{2\rho_1 p_1^2}\right\}^{-1}$$

and by the following table indicates the nature of the agreement between the calculated and observed values.

Gas	$\frac{(K_1-1)\pi A\eta^2}{2\rho_1 p_1^2}$	d Observed[7]	D Calculated	D Observed[8] +	D Observed[8] −
Air	3.70	.150	.032	.028	.043
H_2	5.39	.131	.205	.123	.190
O_2	3.56	.189	.041	.025	.040
CO_2	2.52	.109	.031	.023	.026

Both in the case of the mobility and in that of the coefficient of diffusion the agreement between the calculated and the observed values is, on the whole, quite satisfactory, the conclusion being that the behavior of the ion can be explained on the supposition that it consists of a single molecule associated with a charge equal to that carried by the monovalent ion in electrolysis.

Mr. Wellisch read an account of this investigation of the mobility and diffusion of the ions before the Cambridge Philosophical Society at its meeting held on

[6] Langevin, *Ann. de Chimie et de Physique*, V., 28, p. 289, 1903.

[7] See Jeans, "Dynamical Theory of Gases," p. 253.

[8] Townsend, *Phil. Trans.*, A, 193, p. 129, 1900.

November 9, 1908, and communicates a paper on the same subject to this section.

Mr. Sutherland, to our regret, is unable to be present at this meeting of the association, but he allows me to communicate to the section a letter of his on the theory of the small ion written to me on February 6, 1908, and permits me to mention the results of his investigation at this stage of our proceedings.

Amplifying the discussion developed in his viscosity paper by the addition, in the energy expression, of a term representing the electrical potential energy of ion and molecule when in contact, Mr. Sutherland, in his letter, proceeds to investigate the relation between the mobility and temperature and deduces for the mobility of the ion the simple expression,

$$k = \frac{A\theta^{\frac{1}{2}}}{+\frac{C'}{\theta - \theta'}}$$

where A is a constant, θ the absolute temperature, θ' the absolute boiling point, under the experimental pressure, of the substance of the gas in which the ions are formed, and C' a constant similar to that represented by C in his now well-known viscosity formula.

To test the theory Mr. Sutherland applies the equation to the experiments of Mr. Phillips[9] on the negative ion, taking $A = 0.1764$, $C' = 150.5$ and $\theta' = 70$, with the following results:

θ	411	399	383	373	348	333	285	209	94
k calculated	2.48	2.42	2.33	2.27	2.13	2.05	1.75	1.22	.235
k observed	2.49	2.40	2.30	2.21	2.125	2.00	1.78	1.23	.235

As will be noticed, the comparison of the mobility calculated from the above expression with the results of Mr. Phillips's valuable series of observations, shows an accordance well within the limits of experimental error, over the whole range of temperature from 95 degrees to 411 degrees absolute. The apparent decrease in the size of the ion with rise of temperature, as discovered by Mr. Phillips, is thus shown to be due to an effect of the ionic charge similar to that of molecular force which accounts for the apparent shrinkage of the molecules in the viscosity problem.

Mr. Sutherland shows, in addition, how his investigation enables an estimate to be made of the diameter of the ion, and concludes from his determination that most probably the small gaseous ion is the ordinary ion of electrolysis.

Mr. Sutherland's expression for the mobility of the ion, by containing a symbol representing the boiling point of the gas substance at the pressure of the experiment, indicates a dependence of the mobility on the pressure of the gas; the comparison of the values given by it have yet to be compared with the results of experiment.[10]

The idea of the small ion as a cluster of a few molecules, founded on insecure assumptions, was perhaps chiefly characterized by its numerical vagueness; its replacement by a definite theory can not but be regarded as marking a great advance in our knowledge of ionic structure.

Turning now to the consideration of the larger ions in the air, it may be said at once that our knowledge is as yet but represented by the mere collection of the results of experimental investigations. The large ions were discovered by M. Langevin[11] in 1905, who found that their movement, in an electric field with a potential gradient of one volt per centimeter, is only at the rate of one three-thousandth of a centimeter per second, but that, under natural conditions, their number is about fifty times as great as that of the small ions. In a later communication MM. Langevin

[9] Phillips, *loc. cit.*

[10] Langevin, *Ann. de Chimie et de Physique*, t. 28, p. 289, 1903.

[11] Langevin, *C. R.*, t. 140, p. 232, 1905.

and Moulin[12] describe an instrument for automatically registering the ionization of the atmosphere caused by the small and the large ions, with which they have experimented during the past few years; from the use of such an apparatus most important information will be derived.

For some time observations of these large ions, in the air at normal pressure, have been made at the physical laboratory of the University of Sydney. In this investigation I have been joined, at times, by students whose names will be given in connection with the mention of results they have obtained, and throughout have been most ably helped by my assistant, Mr. Carl Sharpe. Owing to the variable character of the natural ionization, the work has proved extremely tedious, as it is only on somewhat rare occasions that a series of observations is accordant enough to give a definite measure of the mobility. The ionization is more uniform after sunset and we observe mainly in the night time.

All our observations have been made with apparatus constructed after the pattern of that used with such success by Professor Zeleny,[13] in his determination of the mobility of the small ions. In such an instrument a uniform stream of air flows through a metal tube which forms the outer conductor of a cylindrical condenser, the ions drifting on to an inner axial electrode, due to the forces in the electric field established between the tube and the axial rod. The theory of the method of finding the mobility with such an apparatus, as given by Professor Zeleny, is well known; it has been followed without modification in calculating the results of the present series of experiments. Greater uniformity in the ionization is obtained if the air, before reaching the measuring tube, is drawn through a considerable length of piping. We have not noticed any effect on the nature of the ions due to the somewhat prolonged contact of the air with the metal of the pipes, and in most of our experiments several meters of iron or of galvanized iron piping have been employed. In all cases Dolezalek electrometers have been used to measure the ionization currents.

During the investigation some definite results have been obtained, of which I propose to give a general account.

In thinking of M. Langevin's discovery the idea must have occurred to many, and is indeed suggested by Professor Rutherford in his book on "Radio-active Transformations," that the large ions may be due to the presence of water vapor. My efforts to elucidate this point have resulted in finding that there is a definite relation between the mobility of the ion and the amount of moisture in the air.

When a current of air is passed over hygroscopic substances, without mechanical filtration, Mr. S. G. Lusby finds that large ions are absorbed and has noticed a loss in number amounting to 55 per cent., after the air had flowed over a tray containing phosphorus pentoxide. I find, in addition, that after leaving the drying agent, those large ions which still exist in the air decrease in mobility with time, and that when the relative humidity changes from 80 to 4 per cent., at a temperature of 19° C., they are not in equilibrium with the new vapor pressure conditions until after the lapse of about twelve minutes. Owing to the variable nature of the natural ionization, and perhaps to other causes, the calculated mobilities exhibit considerable irregularities, but show in an unmistakable manner, when the equilibrium state is established, a dependence of the mobility on the amount of water vapor in the air, the relation between the two

[12] Langevin and Moulin, *Le Radium*, 4, p. 218, June, 1907.

[13] Zeleny, *Phil. Trans.*, A, 195, p. 193, 1900.

quantities being apparently a linear one between the limits of the absolute humidity represented by 0.5 and 19.0 (grms./m^3), corresponding to relative humidities of 4 and 100 per cent. The mean mobilities for these values of the humidity, from results so far obtained, are 1/1280 and 1/3370, respectively. In other words the mobility for an absolute humidity of 2.4 is twice as great as that for a humidity of 15.4 (grms./m^3). The observations are not regular enough to show if there is any difference between the mobilities of the positive and negative ions. Owing to ionization being caused by phosphorus, it is not advisable to use phosphorus pentoxide as the drying agent in such experiments, and calcium chloride has been employed in all cases.

The intermediate ion has been under observation for only a comparatively short time. The measures so far made, however, show that the mobility is largely affected by change of the humidity of the air, the magnitude varying from one fifteenth to about one tenth of that number as the absolute humidity alters from 0.5 to 15 (grms./m^3) at a temperature of about 22° C. To this statement there is a limitation, the extent of which I do not as yet fully know—in air in its natural state with the absolute humidity between 14 and 16 grms./m^3, at 22° C. when the ionization due to this class of ions is relatively weak, the mobility, at least of the positive ions, is of the order of 1/65, while with strong ionization the value is only about half as great. Unless the limitation just mentioned provides an exception, on further investigation, no definite difference between the mobilities of the positive and negative ions of this class can be deduced from the observations.

The facts just described prove that there is a definite connection between the ions and the water vapor of the air, and open up an interesting field for speculation as to the development and structure of electrified clusters, and as to the nature of the resistance which they experience in drifting through the crowd of molecules. The basis of the structure is, of course, the molecular ion, which, it is well known, originates from effects associated with radio-active transformations occurring in the air, the ionization being primarily due to the presence of radium and thorium in the material of the earth's surface. The growth to more complex structure apparently occurs by the collection of water molecules round the molecular ion, owing to the influence of its charge.

Seemingly from a consideration of the experimental results, we must recognize at least two forms of electrified molecular aggregation in the air which are stable under ordinary conditions. As the mobilities depend on the humidity, it might not unreasonably be supposed that the intermediate and large ions represent stages in the development of the small ions into visible drops of water, which occurs if the air becomes sufficiently supersaturated. It seems, therefore, curious that the large ions are not separately apparent as condensation nuclei in cloud experiments.

Mr. C. T. R. Wilson[14] has shown that in such experiments the presence of a moderate electrical field prevents the formation of drops if the expansion ratio does not exceed the value 1.27. This proves that the nuclei for these small expansions are ions which can be removed by the field before the expansion takes place. I have carefully repeated the observations, with an apparatus similar to that described by Mr. Wilson, in order to determine if the effect of the electric field varies with the time it is on before expansion, and find the full effect whether the interval is one second or twenty minutes. With the fields

[14] Wilson, *Phil. Mag.*, June, 1904.

used it takes several minutes to remove all the large ions, on account of their small mobility, whereas the small ions disappear in less than a second, so the nuclei for the drops formed with expansions below 1.27 are small, not large ions. To test whether the large ions become visible at a lower humidity than that at which the small ones appear, Mr. E. P. Norman, at the Sydney University Laboratory, has repeated Mr. Wilson's experiments on the supersaturation required for condensation,[15] with natural air over mercury. Commencing with a humidity between 60 and 70 per cent., after removing the "dust," no condensation occurs, not only below saturation, but not until the supersaturation becomes four-fold, as in the earlier experiments over water. In all our experiments the observations have been repeated with air which has remained undisturbed in the apparatus overnight, in order that time might be available for the reproduction of the large ions if they had been initially withdrawn, but the results of the first expansion in the mornings appeared in no case different from those of the later ones. Now Mr. Lusby finds, using two Zeleny tubes in series, joined by earthed piping whose length can be varied, that if all the large ions are removed from a stream of air by the first tube, they are fully reproduced in number in about 22 minutes. Our failure to detect the large ions is not, therefore, because they were removed with the "dust," unless, indeed, large ions are not produced in closed vessels, a matter which it would be difficult to determine.

Considering that in natural air the large ions are fifty times more numerous than the small ones, it is hard to reconcile the fact that the separate existence of the former has never been suspected in condensation experiments with the idea of the large ion as representing a stage in the growth of the small one to a condition of visibility, and the experimental evidence as to the position of the large ion in this connection seems as yet in an unsatisfactory state.

MM. Langevin and Moulin[16] describe the small and the large ions as playing different parts in the formation of natural clouds, but the statement is merely one of suggestion.

As all the ions have the same charge, the electrical state of the atmosphere is conditioned by the numbers of the ions of each class which exist at the time. Should the numbers of positives and negatives be equal the air is electrically neutral, if, however, one kind greatly outnumbers the other the air is thereby highly electrified.

The number per cubic centimeter, or the specific number, as it may be called, of each class of ions in the air is an extremely variable quantity, particularly in the day time. From measurements in other parts of the world it is considered that the specific number of the small ions varies between 500 and several thousands. Between this estimate and that given by my own experience there is an amazing discrepancy. In a series of 128 observations, taken at Sydney in the early part of the year 1907, the maximum specific number is 157, the minimum zero, the mean number for the positives being 39 and that for the negatives 38. The European determinations are based on observations taken with Dr. Ebert's well-known ion counter, the principle of the apparatus being that of the Zeleny tube. With our present knowledge of the existence of the intermediate ions, it can readily be shown that the inner electrode of the instrument is altogether too long. The apparatus, as ordinarily employed, catches not only the small ions, but a proportion of the others as

[15] Wilson, *Phil. Trans.*, A, 189, p. 265, 1897.

[16] Langevin and Moulin, *loc. cit.*

well. Calculating with my own measures of the mobilities and specific numbers, it appears that the determination of the specific number of the small ions from the indications of the Ebert instrument must be from two to four times too great. As for the remaining part of the discrepancy, having used Dolezalek electrometers in my own observations, I may, perhaps, be prejudiced in thinking that the metal leaf electroscope of the Elbert apparatus is an unreliable appliance for use in such determinations; in any case the matter must be made the subject of a special enquiry, but in the meantime I have the utmost confidence in my own measures.

With regard to the other ions, from the very limited series of observations which I have as yet made of the intermediate ones, in air in its natural state, what I have previously called relatively strong ionization is represented by about one thousand per cubic centimeter, while for the relatively weak ionization the number is about two hundred.

For the specific number of the large ions, a series of 117 observations gives 5,500 as the maximum and 600 as the minimum, the mean for the positives being 1,914 and for the negatives, 2,228.

The numbers given, with the exception of those for the intermediate ion, are the results of measures with air drawn directly into the testing apparatus without the intervention of any pipes; later observations give much higher values for the specific number of the large ions in air led through a considerable length of piping.

It is now well known, since Lord Kelvin's memorable work on the subject, that a potential difference exists between the earth's surface and the upper layers of the atmosphere. In the electrical field, which is thus indicated, the ions in the air move more or less steadily in a vertical direction, the negatives ordinarily traveling upwards, the positives downwards to the earth. Such a movement constitutes a vertical electric current in the air, the magnitude at any time depending on the air's specific conductivity and the value of the potential gradient at the moment. The specific conductivity is represented by the sum of the continued product of the specific number, the mobility, and the charge for each class of ion. An instrument designed by Dr. Gerdien, in which an electroscope is used as in the Ebert apparatus, has been universally employed for such determinations as have been made of this important quantity. It measures the sum of the conductivities due to each type of ionization, and the calculation of the result from observations with the apparatus is not affected by the discovery of a new class of ions. The complexity of the natural ionization, however, prevents the instrument being used to accurately determine the specific number of the small ions. The average value of the specific conductivity of the air in other parts of the world, as given by the Gerdien apparatus, is about 10^{-4} in electrostatic units.[17] The magnitude of this quantity can be calculated from the measures of the mobilities and specific numbers of the ions, and the average specific conductivity of the air at Sydney, so determined, is only about one tenth of the value just stated. Here again there is a considerable discrepancy between my own and other measures which has yet to be investigated.

With increasing knowledge we can look forward to developments of importance to meteorology in connection with ionic observations; just now it is doubtful, I think, if valuable effort is not being wasted as a result of over-confidence in the present state of the art.

[17] Gerdien, *Gessell. Wiss. Gottingen, Nachr.*, Math-Phys. Klasse, 1, p. 77, 1907. Dike, *Terr. Magn. and Atmos. Elect.*, September, 1908.

Such is a sketch of our present knowledge of the ions of the atmosphere. With the publication of Mr. Wellisch's and Mr. Sutherland's investigations we have reached a definite idea of the small ion in air—a molecule, which, as the attraction of its charge brings about collisions which would otherwise not occur, acts as if it were one of more than the normal size—the conception enabling our experience to be not only simply but exactly described. Of the large ions, no such definite picture can as yet be drawn. Ions similar in character have been observed in gases from flames and in other cases, and it is to be hoped that the material which is now being collected may soon prove sufficient, in the hands of those specially skilled in the methods of the kinetic theory of gases, for a discussion of the life history of these molecular clusters. The study of the natural ions has a special interest, as a wider determination of the facts of the ionization of the air means an advance towards a more comprehensive knowledge of atmospheric electricity.

J. A. POLLOCK
UNIVERSITY OF SIDNEY

THE ELIZABETH THOMPSON SCIENCE FUND

THE thirty-fourth meeting of the board of trustees was held at Harvard College Observatory, Cambridge, Mass., on April 29, 1909. The following officers were elected:

President—Edward C. Pickering.
Treasurer—Charles S. Rackemann.
Secretary—Charles S. Minot.

It was voted to close the records of the following grants, the work having been completed and publications made: No. 115 to H. S. Carhart, and No. 128 to L. J. Henderson; and to close upon receipt of publications the accounts of the following grants: No. 96, H. E. Crampton; No. 103, E. Anding; No. 112, W. J. Moenkhaus; No. 126, L. Cuénot; and No. 132, W. G. Cady.

Reports of progress were received from the following holders of grants:

No.		No.	
98.	J. Weinzirl.	137.	C. H. Eigenmann.
111.	R. Hürthle.	138.	Mme. P. Šafarik.
117.	E. Salkowski and C. Neuberg.	139.	J. Koenigsberger.
119.	J. P. McMurrich.	140.	K. E. Guthe.
123.	E. C. Jeffrey.	141.	J. T. Patterson.
131.	F. W. Thyng.	142.	W. J. Hale.
133.	J. F. Shepard.	143.	R. W. Wood.
135.	A. Negri.	144.	G. A. Hulett.
136.	H. A. Kip.	145.	J. de Kowalski.
		146.	M. Nussbaum.

The secretary stated that during the past year no reports had been received from the following holders of grants:

22, 27.	E. Hartwig.	121.	A. Debierne.
109.	A. Nicolas.	124.	P. Bachmetjew.

It was voted to make the following new grants:

No. 147. $200 to Professor Johannes Müller, Mecklenburg, Germany, to investigate the physiological chemistry of inosit.

No. 148. $200 to Professor C. C. Nutting, Iowa City, Iowa, for a report on the Gorgonacea of the Siboya Expedition.

No. 149. $200 to Professor Ph. A. Guye, Geneva, Switzerland, for determinations of atomic weights.

No. 150. $100 to Professor Charles A. Kofoid, Berkeley, Cal., for an investigation of the life history of the Dinoflagellates.

No. 151. $150 to Professor Otto v. Fürth, Wien, Austria, for a research concerning the relation of the internal secretion of the pancreas to the general metabolism and especially to the combustion of carbohydrates.

No. 152. $150 to W. D. Hoyt, Esq., Baltimore, Md., to study the fruiting of the marine alga, *Dictyota dichotoma*.

No. 153. $250 to W. Doberck, Esq., Sutton, England, for a position micrometer to be used in astronomical observations.

No. 154. $100 to Dr. J. P. Munson, Ellensburg, Washington, for an investigation of the minute structure of the chelonian brain.

CHARLES S. MINOT,
Secretary

THE RETIREMENT OF PRESIDENT ELIOT

THE faculty of arts and sciences of Harvard University has passed a minute on the services of President Eliot which reads as follows: